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Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
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VERY LARGE TELESCOPE

3HE Cabinet Cooling System
Technical Manual

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1. INTRODUCTION

The thermal constraints for the VLT Observatory require that the temperature of the equipment in the telescope area is kept as close as possible to ambient air temperature. A cooling system for Electronic Cabinets is required to extract the heat dissipated inside the cabinets in order to minimize the thermal pollution of the environment. This is done with an actively controlled system, which cools the Electronic Cabinets using cooling liquid supplied throughout the Observatory.

ESO has developed three different standardized Thermal Control Systems for electronic cabinets:

- 1HE Cooling Controller (see [RD7])
- 3HE Cooling System (described in this document)
- 4HE Cooling System (see [RD1]).

The 4HE system was designed for use in large cabinets with relatively high internal power dissipation, and is used for most control systems throughout the Observatory. For smaller Cabinets, however, the 4HE Cooling System is not suitable because of its large form factor.

The 1HE system is basically the 4HE system electronics mounted in a separate chassis without heat exchanger. This may be used where an external heat exchanger is required.

Some sub-systems have relatively small heat dissipation, or might be located in small cabinets. A typical application is cabinets mounted directly on Instruments where physical space is limited. Here it is not possible to use the large 4HE cooling system. For such application a smaller system was developed. This 3HE cooling system has the same basic functional principle as the ESO 4HE Cooling System [RD1]. The difference is physical size and cooling capacity.

1.1. PURPOSE

This document is a technical manual for the 3HE Cabinet Cooling System. The document describes, in detail, the cooling unit and contains detailed schematic drawings.

1.2. SCOPE

Chapter 2 introduces the operating principle of the 3HE Cabinet Cooler. In chapter 3 and 4 the analogue electronics and the OMEGA Temperature Controller are described, including Controller parameterization.

Installation and external connection is described in Section 5.

1.3. APPLICABLE DOCUMENTS

None.

1.4. REFERENCE DOCUMENTS

[RD1] VLT-MAN-ESO-17130-1603 VLT Electronic Cabinet Cooling System User Manual

[RD2] Dual PT100 Sensor Box. Issue: 1.1

[RD3] OMEGA CN76000 Operator's manual M1303/0991

[RD4] OMEGA CN77000 User's Manual

[RD5] OMEGA CN77000 Specifications

[RD6] Microinfinity 1.1 Help File

[RD7] VLT-MAN-ESO-17130-2027 VLT Electronic Cabinet thermal Control Unit

2. SYSTEM DESCRIPTION

Since the OMEGA CN76130-485 controller is not produced anymore, the new 3HE Cooling Systems are equipped with the OMEGA CN77330-C4 controller.

2.1. COOLING UNIT

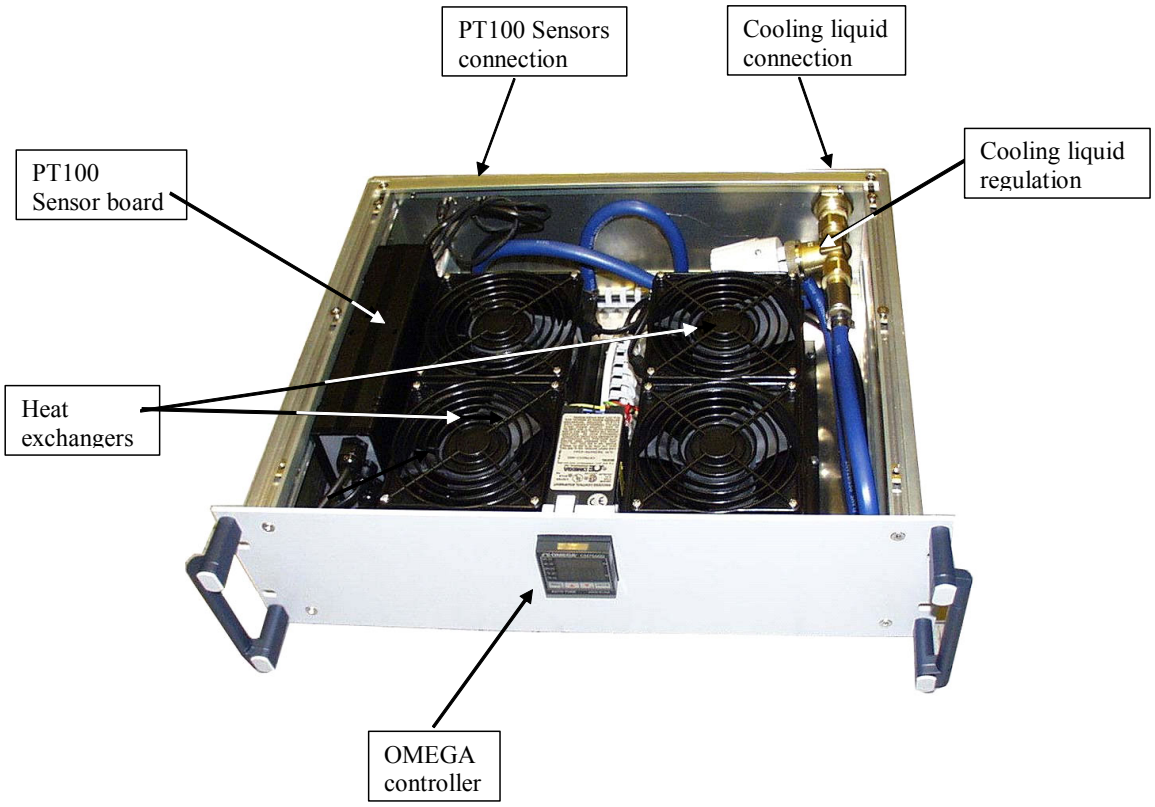


Figure 1 Cooling Unit (top view)

The Cooler is integrated into one 19" unit. The main elements are:

- Heat Exchangers with fans (2x)
- OMEGA CN76130-485 Temperature controller (old version) or OMEGA CN77330-C4 Temperature controller (new version)
- PT100 Sensor electronics board
- Cooling liquid regulation valve

The airflow is from bottom of unit (warm air intake) to top of unit (cooled air outlet).

2.2. BLOCK DIAGRAM

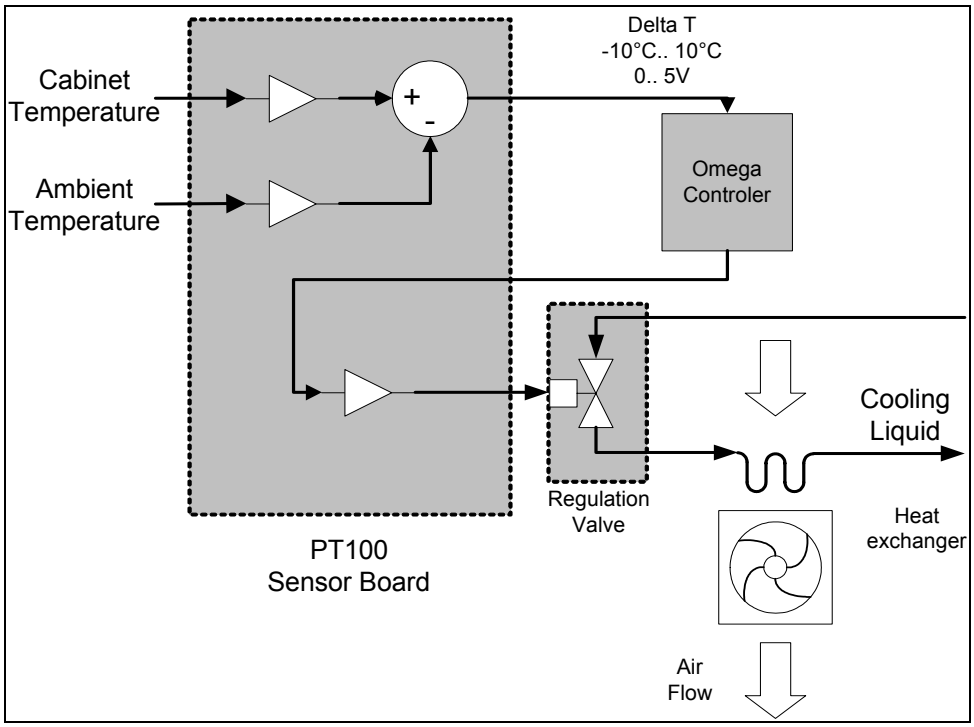


Figure 2 Block Diagram

The input to the system comes from two PT100 temperature sensors:

- Ambient air temperature
- Cabinet surface temperature

The two sensor signals are linearised and amplified on the PT100 sensor board, see Figure 1 and Figure 2. The delta temperature (defined as $T_{cabinet} - T_{ambient}$) is generated in an analogue differential amplifier. The gain is calibrated to a span of 0..5 VDC for a delta temperature (Cabinet minus Ambient) in the range -10°C..+10°C. The sensor input range is -50°C..+50°C.

This delta T signal is connected to the OMEGA temperature controller input. The OMEGA controller is set up to control cooling liquid flow by applying PWM signal to the Regulation Valve. This valve has a thermal actuator, which opens/closes water flow.

Airflow is forced through the heat exchangers by means of four axial fans.

3. PT100 SENSOR BOARD

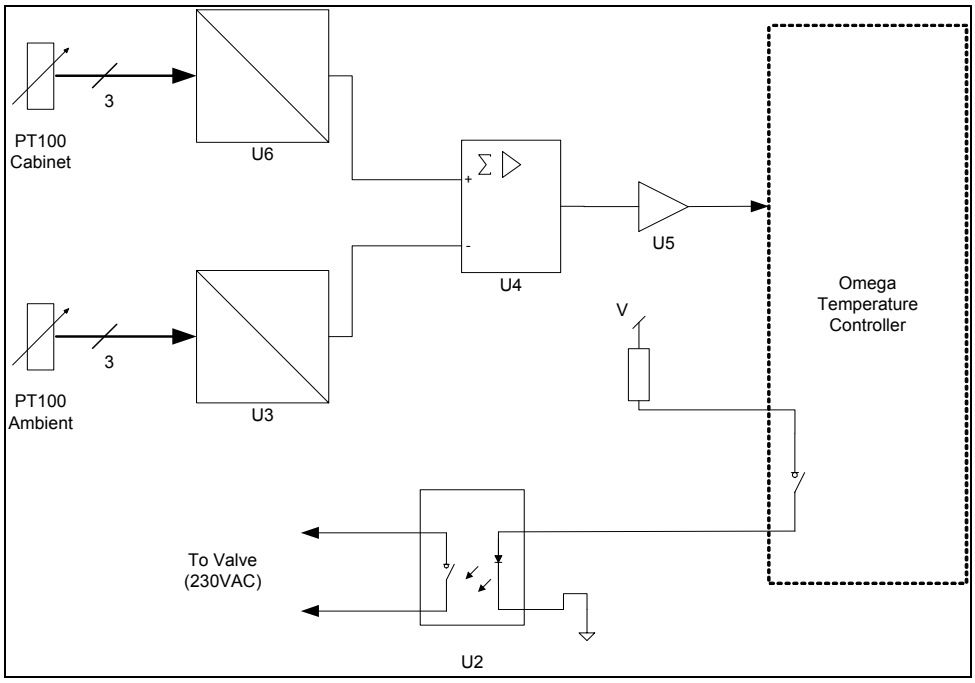


Figure 3 PT100 Sensor Board block diagram

This board processes the two PT100 sensor signals. The sensor input range is set to -50°C.. +50°C. Sensor signals are linearised, and converted to DC voltage 200mV..1000mV in U6 and U3. Those two DC signals are fed to a differential amplifier U4, where the temperature difference Delta T = T(cabinet) - T(ambient) is converted to a voltage 0..5 VDC, corresponding to a Delta T of -10°C..+10°C. This signal is buffered in U5, and connected to the OMEGA temperature controller. A relay contact output is controlling cooling liquid valve position by means of (slow) PWM modulation with a cycle time of 14 seconds. The valve coil is actuated by 230 VAC. An opto-isolated semiconductor relay mounted on the PT100 sensor board minimizes OMEGA controller output relay load. A LED “SP1” on the OMEGA controller front panel is lit during the 230VAC is applied to the Valve (closing of Valve).

A small linear power supply generates +12 VDC for circuit supply. The PT100 Sensor board detailed schematic drawing is presented in Appendix 2.

Note : In case of power failure, either 230 VAC or V (in Figure 3), the Coolant regulation valve will open fully.

4. OMEGA CONTROLLER

4.1. CONTROL PRINCIPLE

A proportional control algorithm is used for temperature control. A proportional band of 2.0 degrees Celsius gives good control accuracy and stability. The valve position, and hereby coolant flow, is set by a thermal actuator with a relatively long time constant, approximately 30 seconds. This is not considered to be a problem, since the controlled thermal process itself has a longer time constant.

Delta T is defined as T(Cabinet) - T(ambient).

The Cooling Liquid valve itself is a “normally open” type. This ensures maximal coolant flow in case of controller failure. When the cabinet surface temperature exceeds ambient temperature (positive Delta T in Figure 4), no voltage is applied to the valve which gives full coolant flow and maximal cooling. If the cabinet temperature is inside the proportional band (2 degrees), the valve position is proportional to Delta T. Below the proportional band (Cabinet surface temperature below T ambient minus 2 degrees) the valve is fully closed, which will stop completely the coolant flow.

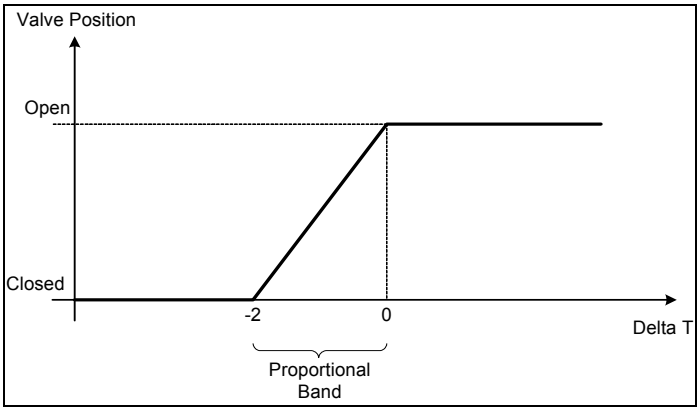


Figure 4 Control characteristics

4.2. OMEGA CN76130-485 CONTROLLER SETUP

The temperature controller is an OMEGA CN76130-485. This is a small process controller with front panel dimensions of 48x48mm (1/16 DIN). It has the following characteristics:

- Front panel display for set point and process value
- Front panel keys for entering of parameters
- Several input types (Voltage, current, Sensor)
- Alarm output (Option)
- Relay control output (Option)
- RS485 communication port (Option) for connection to Host (LCU)

Figure 5 OMEGA CN76130-485 temperature controller

Two values are displayed simultaneously on the front panel (see Figure 5), the Process Value (PV, upper display) and the Set Value (SV, lower display).

The user has access to three "menus" for Controller configuration and parameterization. These are:

- Primary menu
- Secondary menu
- Secure menu

See also [RD3] for more information about the controller.

If any entered parameters are out of range or logically wrong, an error message will be displayed. Refer to [RD3] for help on error messages.

When setting up a controller "from scratch", it is recommended to start in the reverse order, by setting Secure menu, then Secondary menu, and last the Primary menu. This is because the menus are dynamic, for instance if the alarm output is disabled in Secure Menu, the alarm value which normally appears in Secondary menu is suppressed.

4.2.1. OMEGA CN76130-485 Hardware configuration

To access hardware configuration switches, open controller by pulling it out of the front panel. Four DIP-switches have to be set for input type selection as shown in Figure 6. The shown setting selects Voltage (0-5 V) input.

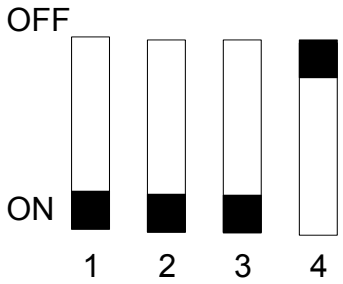


Figure 6 DIP switch setting

4.2.2. OMEGA CN76130-485 Parameters configuration

Table 1 Secure menu parameters

Display	Parameter	Value
SECR	Menu access password	4 (disable password)
INP	Input type	Volt (Voltage input)
OSUP	Zero suppression	Off (select 0-5 V)
UNIT	Front panel unit indicator	C (Celsius)
DPT	Decimal point	0.00
INPT	Input fault timer	Off
SENC	Sensor rate of change	Off
SCAL	Scale Low	-10.00
SCAH	Scale high	+10.00
SPL	Set point Low	-10.00
SPH	Set point High	+10.00
SP1O	Set point 1 Out	OutA
S1OT	Set point 1 Type	Cy (PWM control)
S1ST	Set point State	Re (Reverse action)
S1OL	Setpoint 1 Output minimum	0 (%)
S1OL	Setpoint 1 Output maximum	40 (%)
S1LP	Set point Lamp	O on
AL	Alarm type	OFF
ADDR	RS485 Address	32
BAUD	RS485 Baud rate	9600
NAT	Network activity timer	OFF
CFLT		1

Table 2 Primary menu parameters

Display	Parameter	Value
SP1	Set point	0.00

Table 3 Secondary menu parameters

Display	Parameter	Value
Auto	Control On/Off	ON
Tune	Control Algorithm	PID
PB1	Proportional Band	2.00
RES	Integral	OFF
RTE	Derivative	OFF
ARUP	Anti Reset Wind-up	OFF
ARTE	Approach time rate	OFF
PEA	Peak recorded value	
VAL	Valley recorded value	
CY1	PWM cycle time	14 (seconds)
PCTO	Percentage output display	OFF
PROG	Ramp/Soak	OFF
STAT	Status display in Home	OFF
1RT	Ramp Time	0.00
1^{ST}	Soak time	0.00
PEND	End of soak	Hold
INPC	Input correction	0.0
FILT	Input filtering	2
LPBR	Loop break	OFF
LORE		LOC
CFSP	Comm failure set point	0.0
ADDR	RS485 address	32

4.3. OMEGA CN77330-C4 CONTROLLER SETUP

Due to the fact that the Omega CN76000 is out of production, the newer 3HE Cabinet Cooling Systems are assembled with the OMEGA controller CN77330-C4. It has the characteristic of the old CN76000 controller with extended options.

Figure 7 OMEGA CN77000 temperature controller

4.3.1. OMEGA CN77330-C4 Hardware configuration

To access the hardware configuration switches, open the controller by pulling it out of the front panel. Seven DIP-switches have to be set for the input type selection. Figure 8 shows the DIP switch settings for a process input type 0-10 Volts.

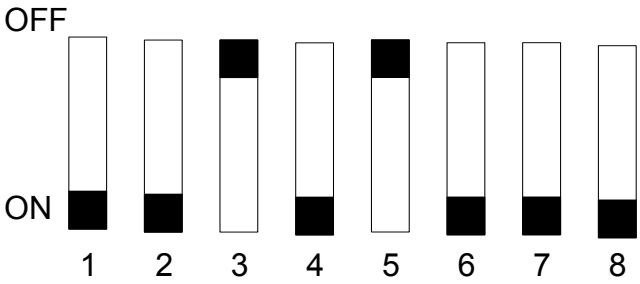


Figure 8 DIP switch settings

For the mechanical and electrical installation please refer to [RD4] and [RD6].

4.3.2. OMEGA CN77330-C4 Parameters configuration

The OMEGA CN77330-C4 can be configured in 2 ways: locally by means of the push buttons and remotely via software by means of the tool “Microinfinity 1.1” provided by the manufacturer of the controller. In the next paragraphs both procedures are described.

4.3.2.1. Serial Communication Parameters

First of all, the Serial Communication parameters of the CN77330-C4 must be locally configured. Table 4 shows the parameters. Please, refer to page 64 of [RD4] for details about the configuration process.

Table 4 Serial Communication Standard Parameters

Communication Parameters	**Value**
Baud Rate	9600
Parity	No
Data	8-bit
Stop	1-bit
Check Sum	No
Line Feed	No
Echo	No[note 1]
Standard	RS-485
Mode	Command
Separation	Space
Address	0032

4.3.2.2. Configuring OMEGA CN77330-C4 locally

The Table 5 shows the software parameters for the OMEGA CN77330-C4 controller. Please refer to the controller user manual [RD4] for details about the configuration process.

Table 5 OMEGA CN77330-C4 Software parameters

Parameter	**Value**
ID Code	0000
Set Point 1 (SP1)	00.00
Set Point 2 (SP2)	00.00
Input Type	Process 0-10V
Alarm 1	Disabled
Alarm 2	Disabled
Output 1 - Self	Disabled
Output 1 - 4-20mA	Disabled
Output 1 - Control type	PID
Output 1 - Auto PID	Disabled
Output 1 - Action Type	Reverse
Output 1 - Anti-Integral	Disabled
Output 1 – Proportional band	0002
Output 1 - Reset	0000
Output 1 - Rate	000.0

[note 1] **Very Important:** In order to configure the CN77330-C4 with the tool “Microinfinity 1.1” the Echo must be set to “Yes”. Likewise, upon completion of the CN77330-c4 parameter configuration, the “ECHO” must be restored to “No”.

Output 1 - Damping Factor	0002
Output 1 – Cycle time	14
Ramp & Soak - Ramp	Disabled
Ramp & Soak - Soak	Disabled
Reading Configuration - Decimal point	XX.XX
Reading Configuration - Filter Constant	16
Reading Configuration - Temperature Unit	C
Reading Configuration - In 1	25.00
Reading Configuration - Read 1	0000
Reading Configuration - In 2	50.00
Reading Configuration - Read 2	10.00

4.3.2.3. Configuring OMEGA CN77330-C4 remotely

The Omega CN77330-C4 can be configured remotely by means of:

- a PC with Operating System win98, win2000, winXP;
- a serial port;
- the RS-232 to RS-485 “I-7520” adapter (Figure 9) provided by Newport Omega ;
- the software tool “Microinfinity 1.1” provided by Newport Omega.

Figure 9 “I-7520” RS232 to RS485 adapter

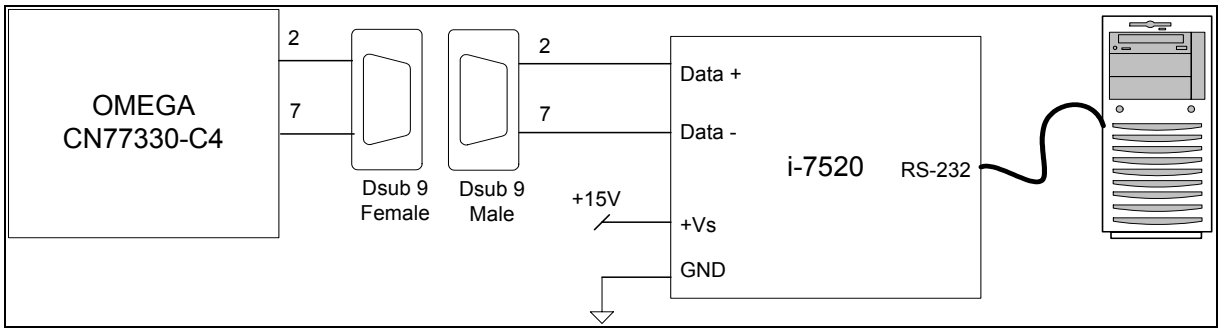


Figure 10 PC – 3HE Cabinet Cooling System connection

Important: The Microinfinity software works correctly if the Regional Settings of your PC have been set to the United States defaults and the Echo Option (see Table 4) has been set to "Yes".

Figure 10 shows the way to connect the Personal Computer to the 3HE cooler in order to establish the communication.

Once the Microinfinity software tool is installed and the communication is set-up, the OMEGA CN77330-C4 can be configured remotely following the steps shown hereafter.

1. Set to "Yes" the Echo option of the CN77330-C4 (see Table 4).

2. Push the Hardware Button of the main window and select the device as in Figure 11.

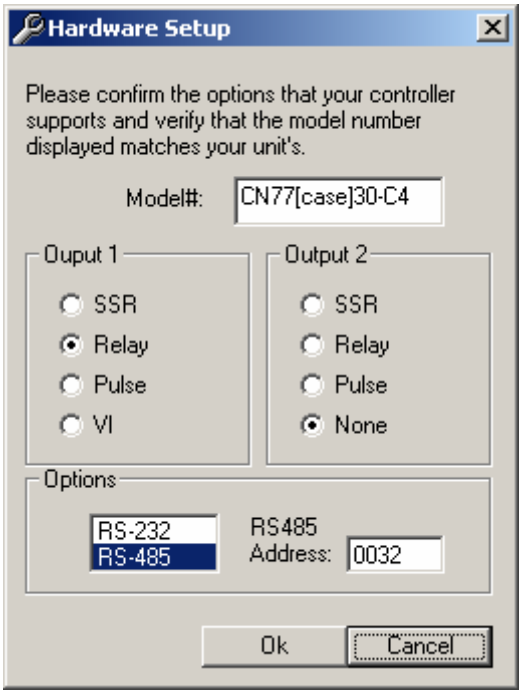


Figure 11 Hardware Setup window

3. Set the Serial com parameter according to Figure 12 and then start the connection wizard.

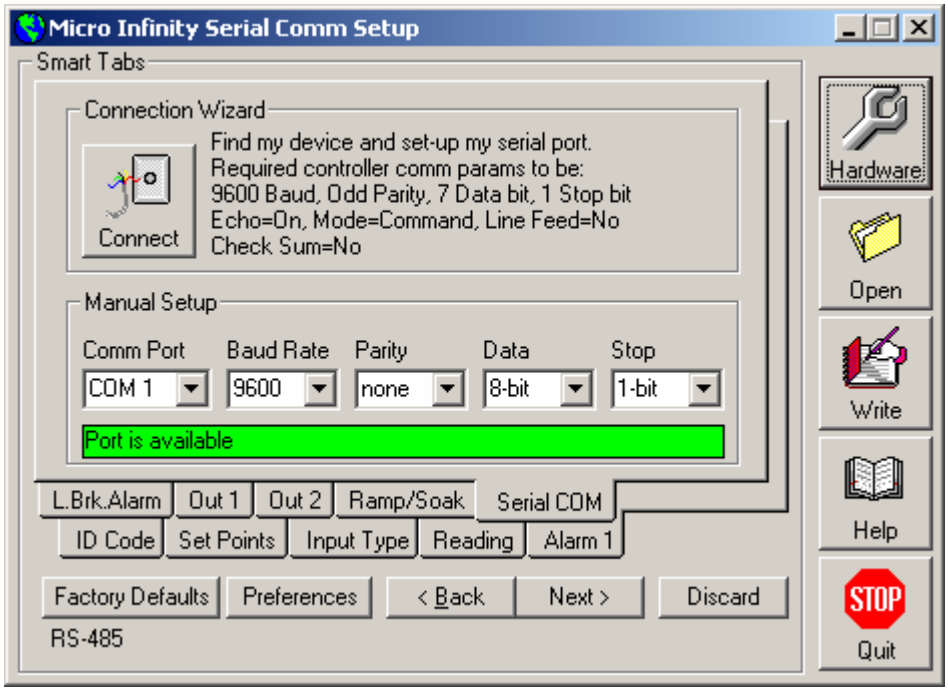


Figure 12 Serial Com tab

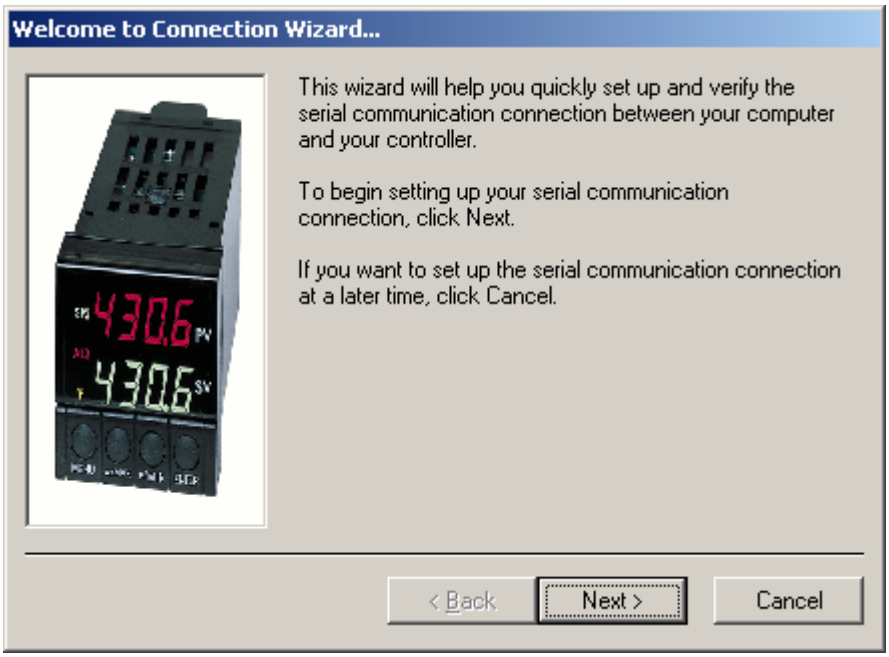

Welcome to Connection Wizard...
This wizard will help you quickly set up and verify the serial communication connection between your computer and your controller.
To begin setting up your serial communication connection, click Next.
If you want to set up the serial communication connection at a later time, click Cancel.
< Back
Next >
Cancel

Figure 13 Connection Wizard – Step 1

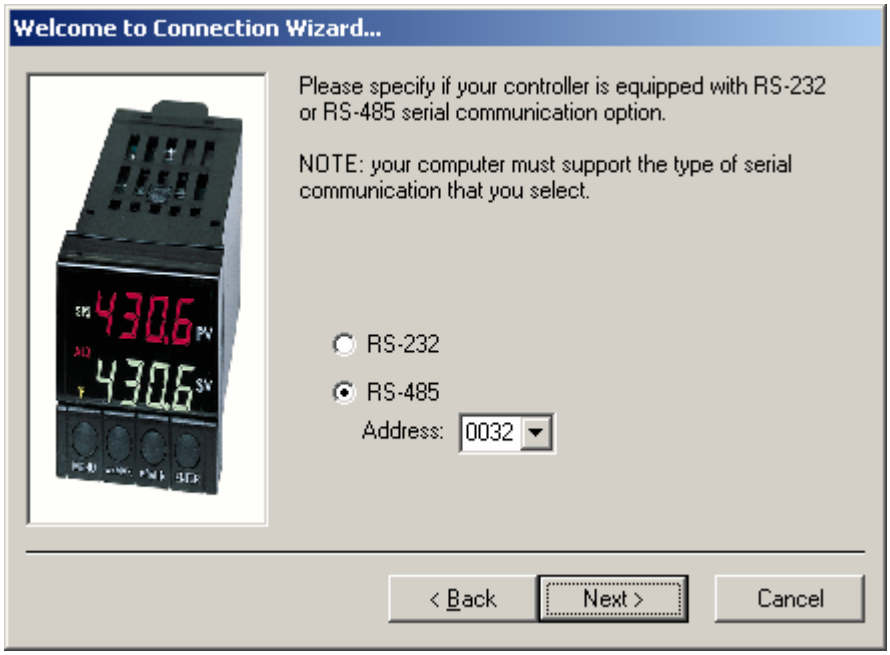

Welcome to Connection Wizard...
Please specify if your controller is equipped with RS-232 or RS-485 serial communication option.
NOTE: your computer must support the type of serial communication that you select.
RS-232
RS-485
Address: 0032
< Back
Next >
Cancel

Figure 14 Connection Wizard – Step 2

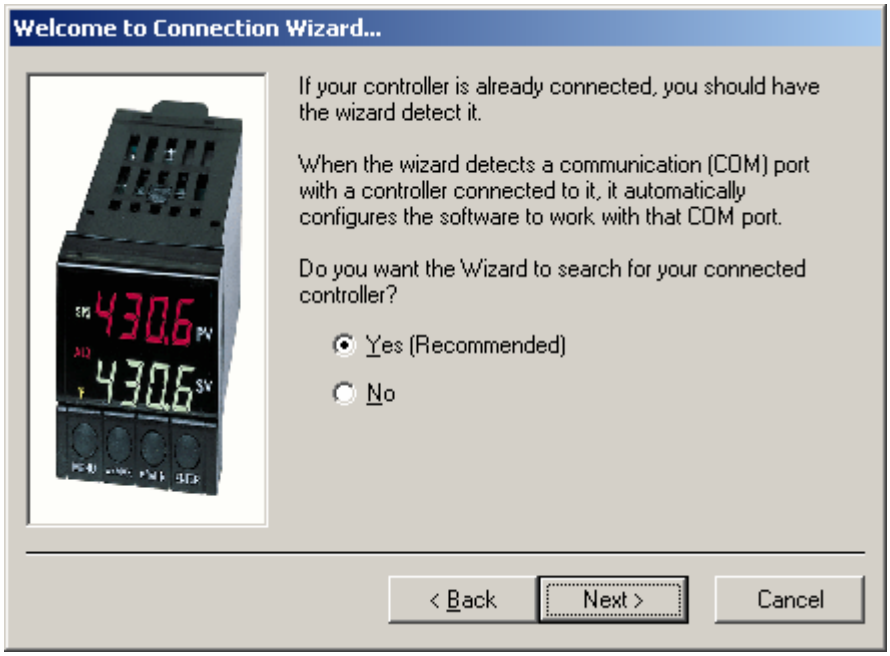

Welcome to Connection Wizard...
If your controller is already connected, you should have the wizard detect it.
When the wizard detects a communication (COM) port with a controller connected to it, it automatically configures the software to work with that COM port.
Do you want the Wizard to search for your connected controller?
Yes (Recommended)
No
< Back
Next >
Cancel

Figure 15 Connection Wizard – Step 3

Welcome to Connection Wizard...
The wizard will now look for the COM port that your controller is connected to.
WARNING: This may take a minute, and could cause your machine to stop responding. Save and close all your programs before beginning detection.
While detection is in progress, you will see a progress indicator. If this indicator stops for a long time, you will need to restart your computer.
To continue, click Next.
< Back
Next >
Cancel

Figure 16 Connection Wizard – Step 4

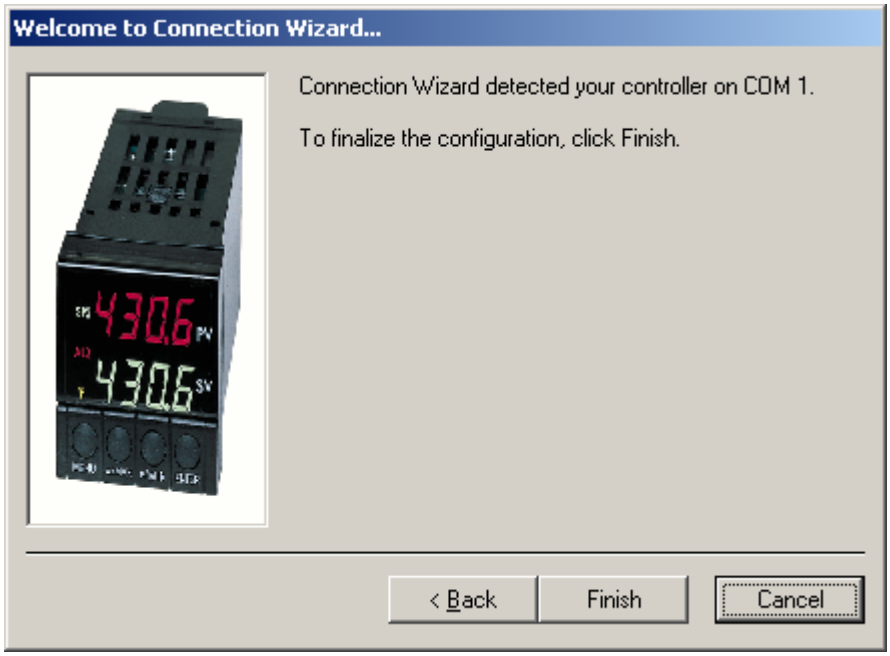


Figure 17 Connection Wizard – Step 5

4. On the ID Code panel set the value according to Figure 18.

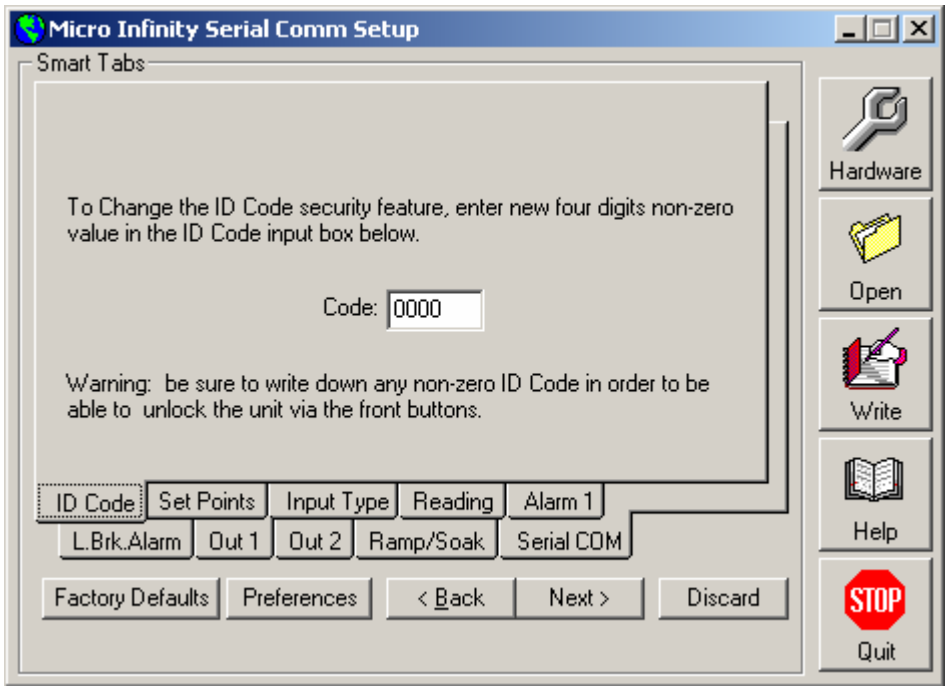


Figure 18 ID Code tab

5. Configure the set points as in Figure 19.

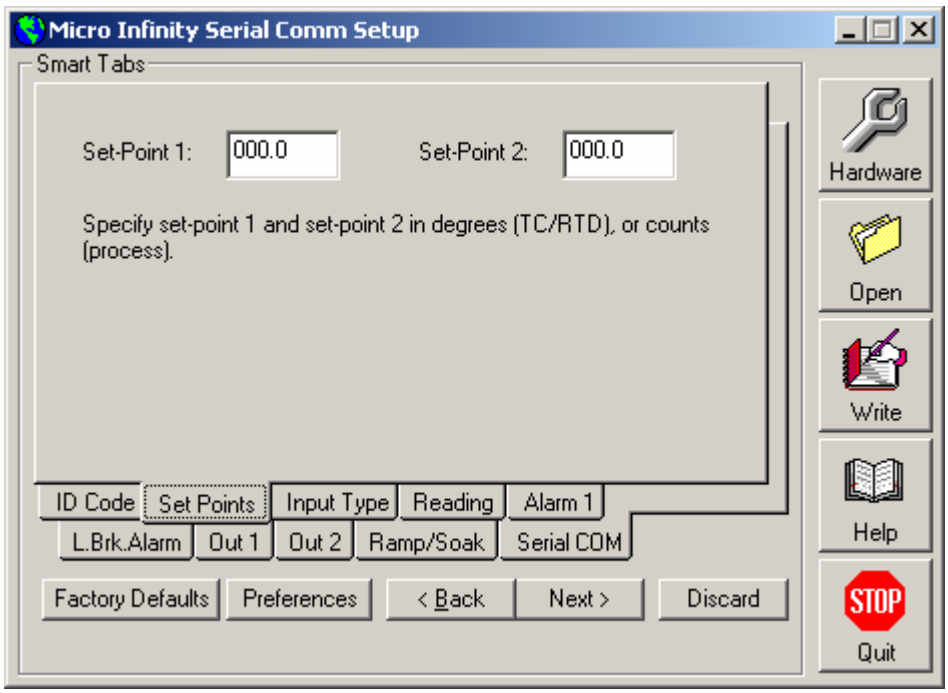


Figure 19 Set Points tab

6. Select the process 0-10V according to Figure 20.

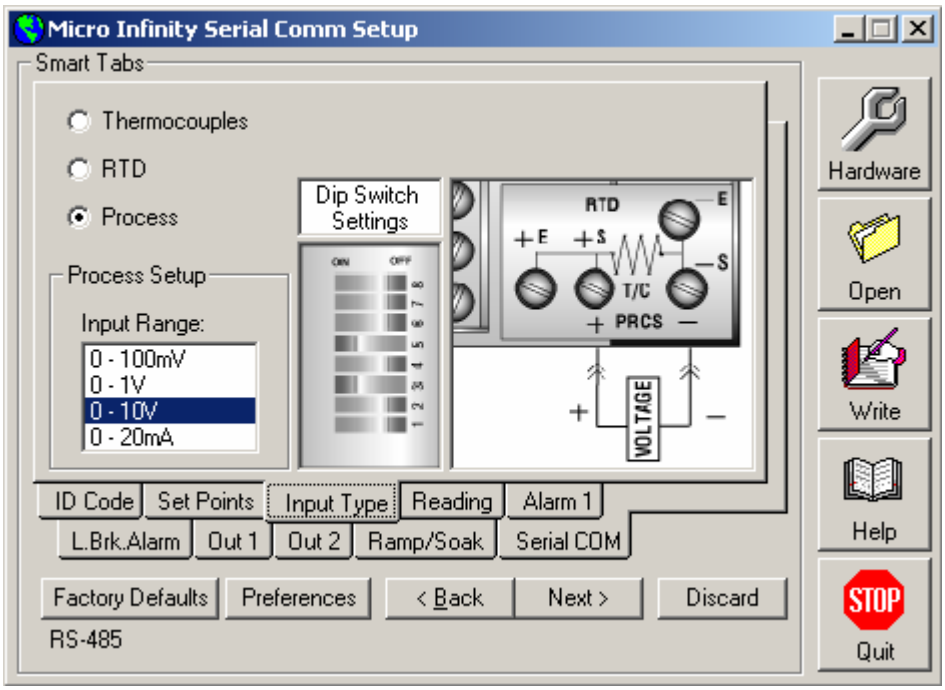


Figure 20 Input Type tab

7. Set the basic setup and the scale/offset as indicated in Figure 21.

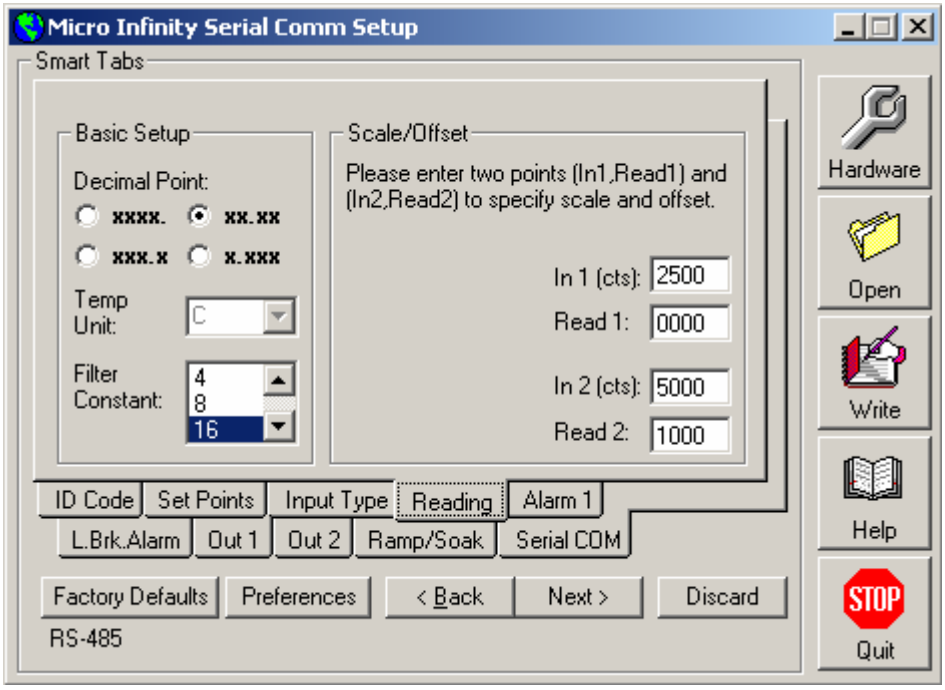


Figure 21 Reading Configuration tab

8. Disable the Alarm 1 (see Figure 22).

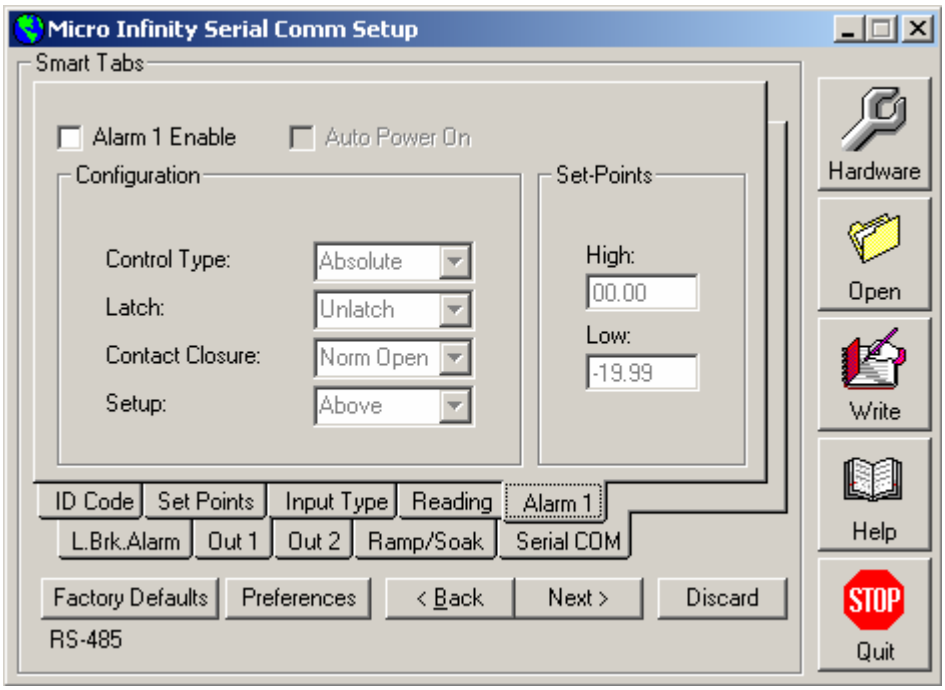


Figure 22 Alarm 1 tab

9. Set the Loop break Alarm as indicated in Figure 23.

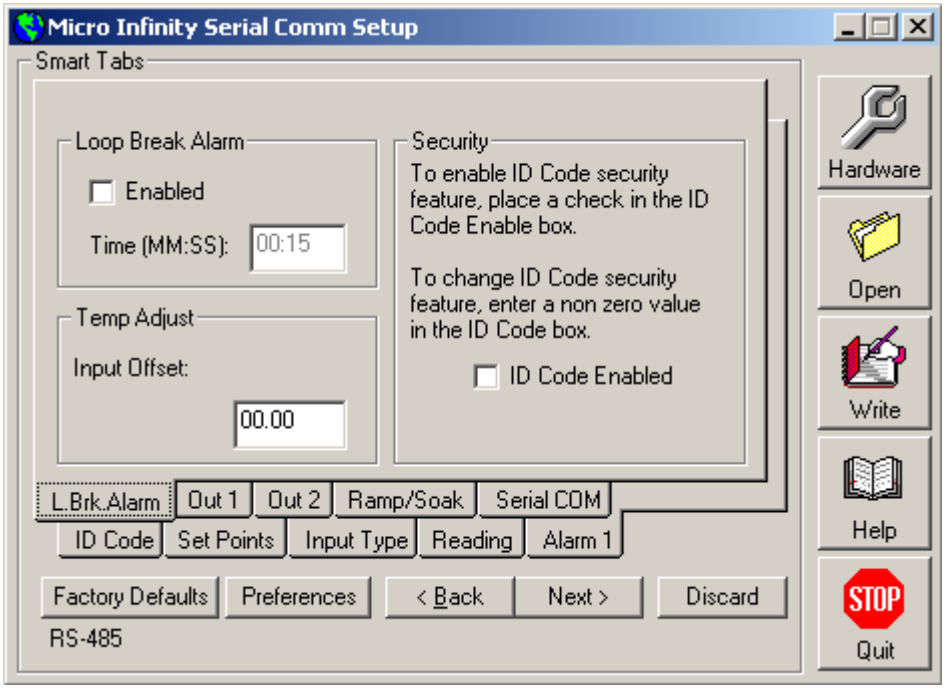


Figure 23 Loop Break Alarm tab

10. Set the control parameters for the Output 1 (Figure 24).

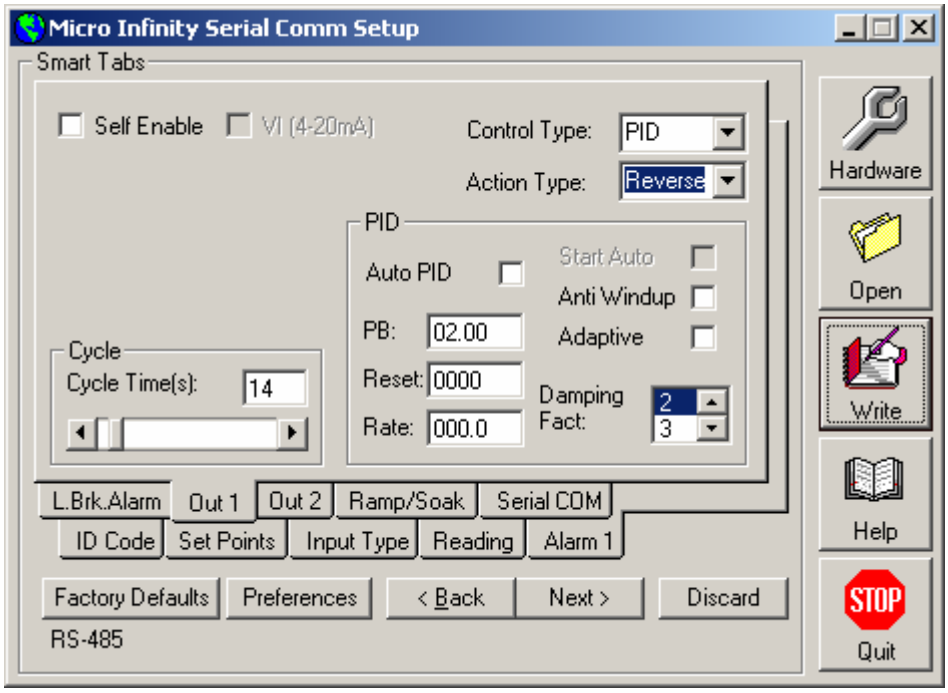


Figure 24 Output 1 tab

11. The values for the Output 2 are not important as the controller has only one output.

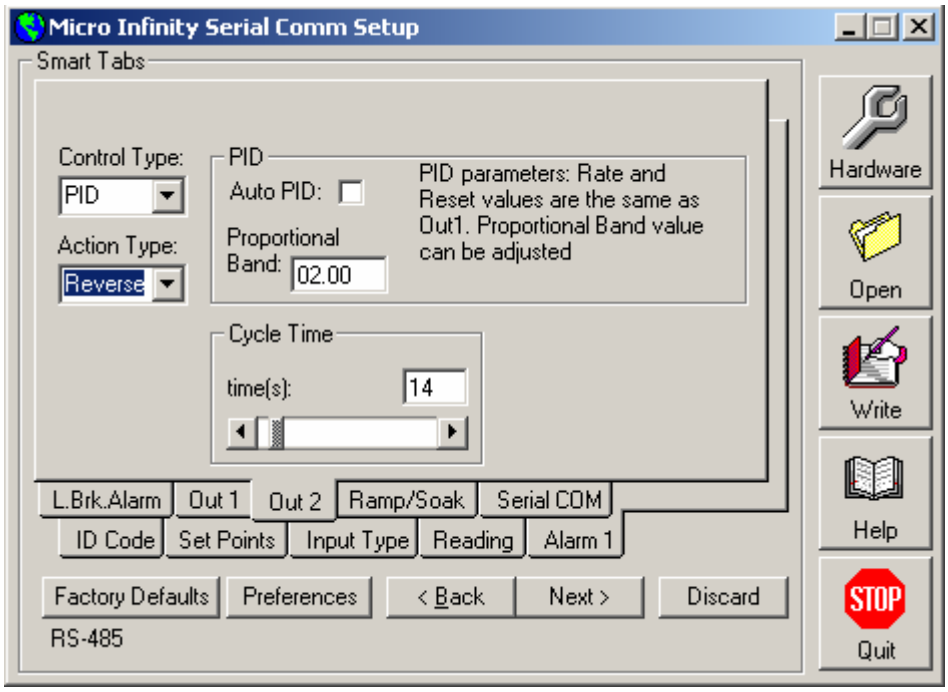


Figure 25 Output 2 tab

12. Disable the Ramp/Soak as in Figure 26.

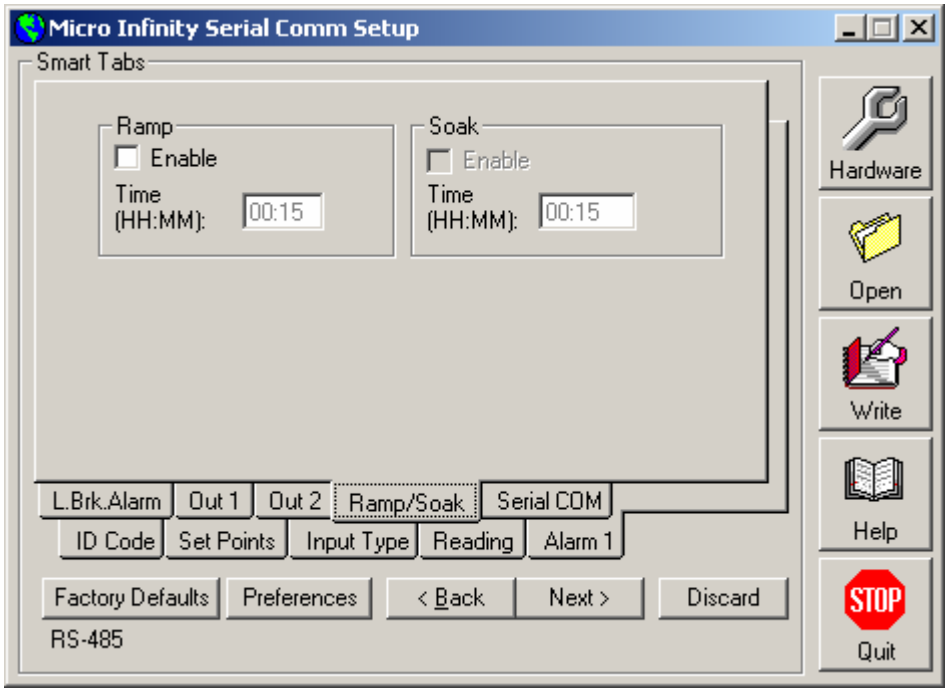


Figure 26 Ramp/Soak tab

13. **Very Important:** Upon completition, the "Echo" option of the CN77330-C4 (see Table 4) must be restored to "No".

4.4. SYSTEM PERFORMANCE

The Figure 27 shows the cooler performance when installed as in Figure 28. The Y-axis shows the temperature difference Delta T = $T_{cabinet} - T_{ambient}$. The sample number is plotted on X. The temperature was sampled every 10 seconds. The cabinet (including cooler) was turned on at Sample #1.

Test conditions:

- Ambient temperature: 16°C.
- Cooling liquid inlet temperature: 8°C.
- Liquid flow rate: not measured.
- Power dissipation in cabinet (VME chassis) : 200 W

After Sample #400 the temperature settles at around –0.5 degrees. In this application, the thermal time constant is around 20 minutes.

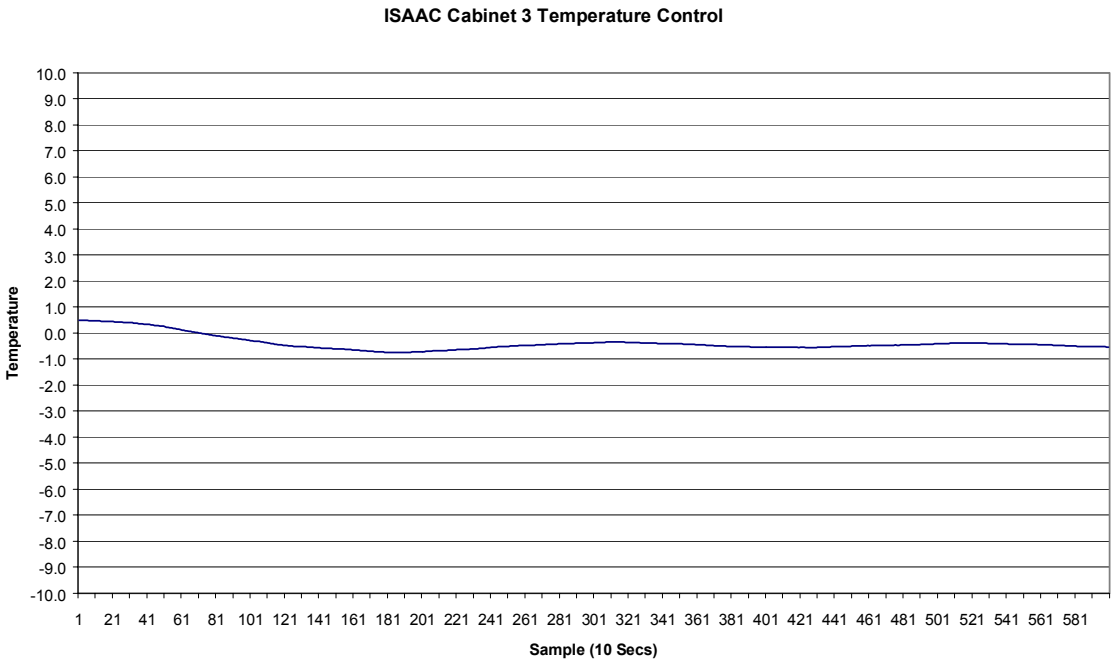


Figure 27 Control performance

5. INSTALLATION

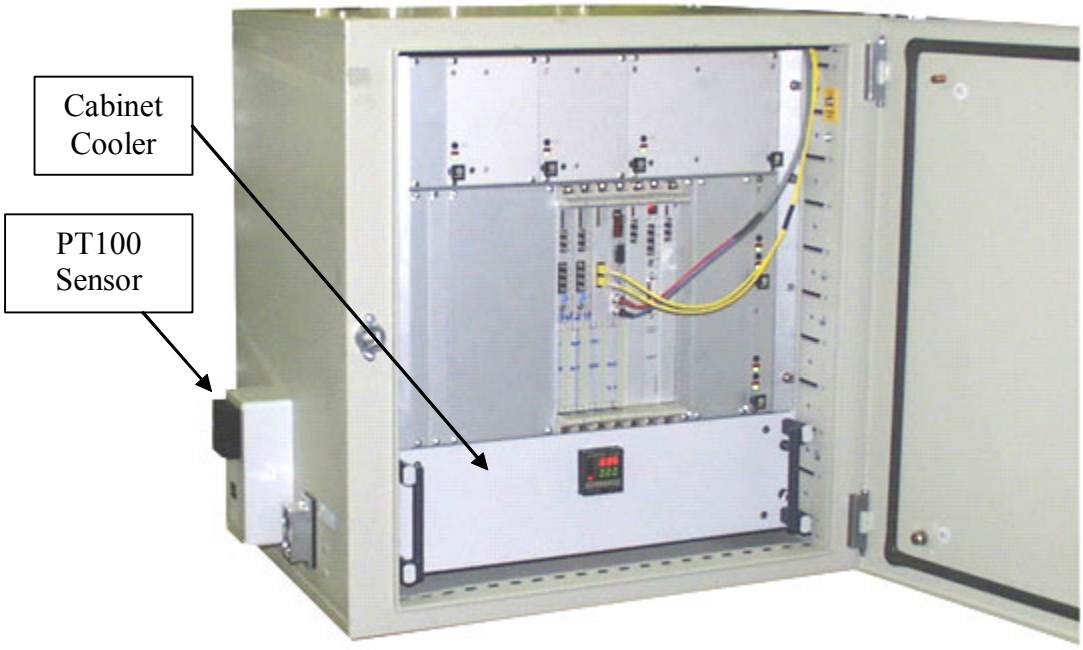


Figure 28 Installed Cooler

The Figure 28 shows a typical installation of the Cabinet Cooler. The cooler is mounted in the lowest position, forcing cold air upward through a 19"-chassis. The warm air is guided down on the left and right sides of the chassis and sucked into the Cooler heat exchangers from the bottom.

On the left outer side of the cabinet, the sensor box is seen. This box has two PT100 sensors, one measuring cabinet surface temperature, the other measuring ambient air temperature. See also [RD2].

For most applications, it is not necessary to mount extra fans in the Cabinet where the cooling system is used. The cooling system heat exchanger fans generate sufficient airflow.

5.1. VME-CRATE COOLING

If the cooler shall be used for cooling of a VME-type crate, as in Figure 28, it is recommended to concentrate the cooled air flow to the VME boards to achieve efficient cooling of the inserted VME boards. Closing the rear part of the cooler chassis with a metal plate, as shown in Figure 30, does this.

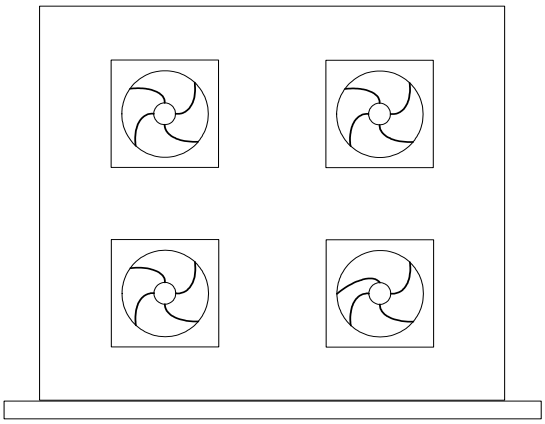


Figure 29 Cooler normal operation (top view)

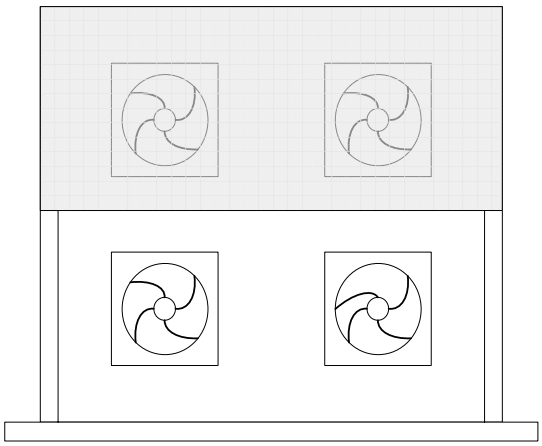


Figure 30 VME-crate cooling operation (top view)

5.2. ELECTRICAL CONNECTIONS

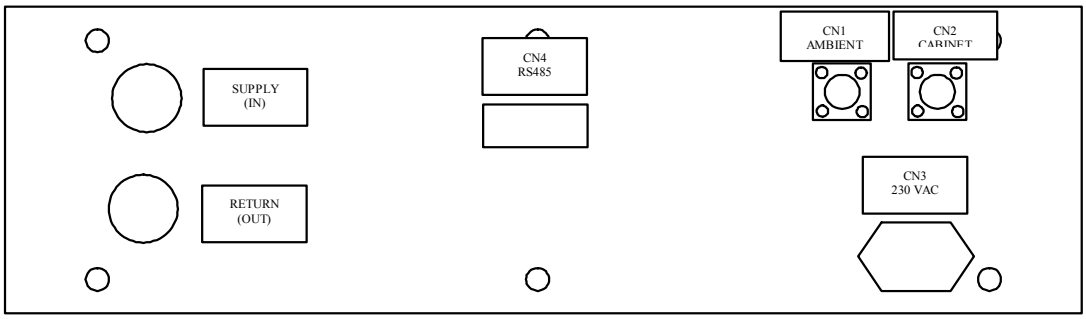


Figure 31 Cooler rear side

All electrical connections are made to the Cooler rear side. There are three connectors:

- CN1 : PT100 Ambient air temperature
- CN2 : PT100 Cabinet surface temperature
- CN3 : 230 VAC power
- CN4 : RS485 serial communication

Refer to [RD2] for detailed information on PT100 connections.

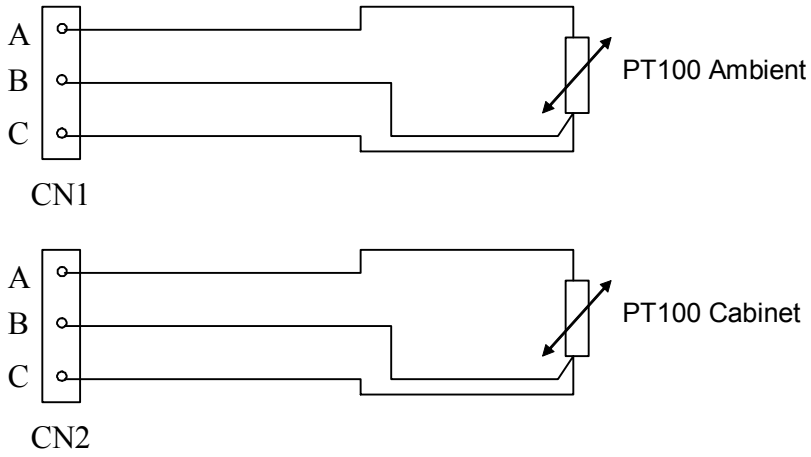


Figure 32 PT100 sensor connection

5.3. COOLING LIQUID CONNECTIONS

Cooling liquid supply/return shall be connected as indicated in Figure 5.2 using the supplied Quick Connectors.

5.4. AIR FLOW

It is left to the user to assure that a proper total airflow inside the cabinet is maintained. The circulating air inside the cabinet should be directed along cabinet outer walls, to avoid hot spots inside the cabinet. For maximum cooling efficiency, make sure that all air is directed in a pattern similar to the illustration in Figure 5.4.

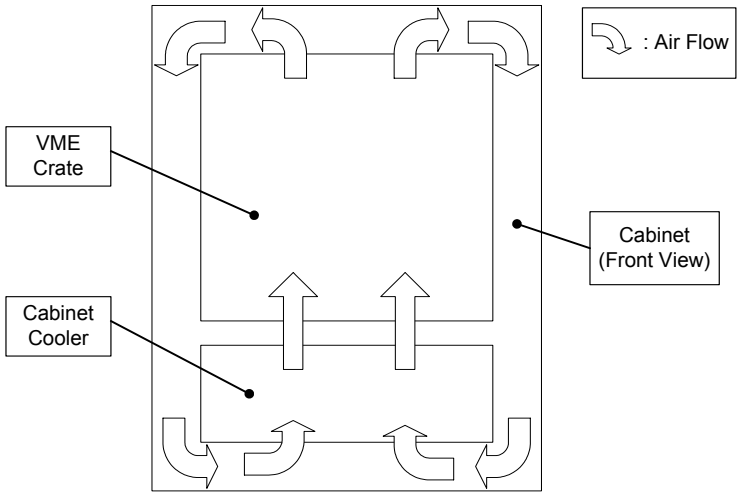


Figure 33 Air Flow

Note: it might be necessary to add more fans in the cabinet in some applications to ensure sufficient airflow.

5.5. RS485 CONNECTION

It is possible (but not necessary) to connect a serial link to the OMEGA controller, thus enabling digital readout of cabinet temperature and OMEGA controller status. Baud rate is user selectable up to 19200 Baud, default setting is 9600 Baud. The physical interface is RS485 two-wire. Note that the pins 4 and 9 are necessary only for the resistor network termination when the connection is with the ISER8 VME board.

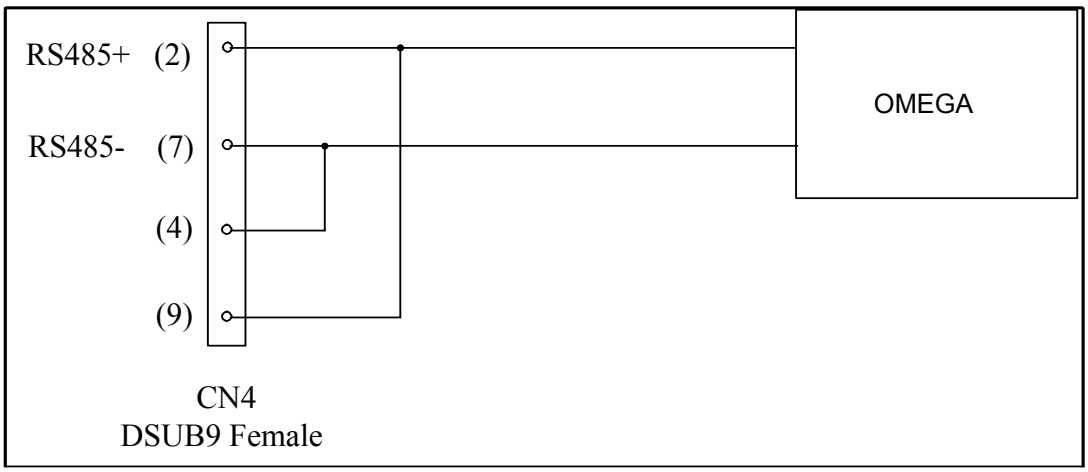


Figure 34 RS485 Connection

6. TECHNICAL DATA

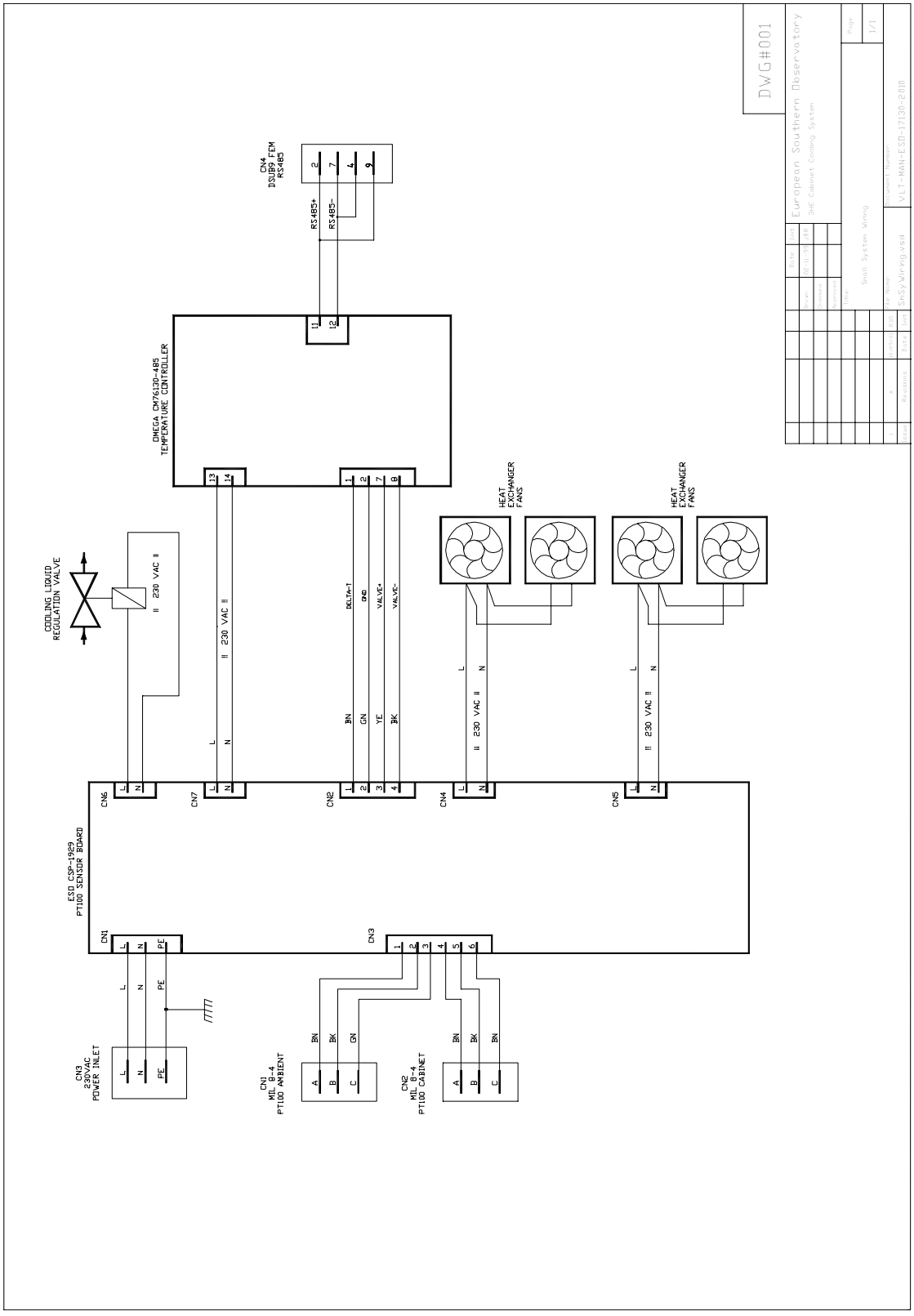
6.1. SPECIFICATIONS

- **Physical dimensions**: H 3HE, W 19", D 360 MM (without rear side connectors)
- **Cooling Capacity** : 300 Watts (Not including Cooler power consumption) assuming cooling liquid inlet temperature 8 degrees below ambient air temperature (VLT compliant), mounting position as Figure 5.
- **Power Supply**: 230 VAC, 110 Watts
- **Cooling fluid pressure** : Maximum 10 bar
- **Electrical Connectors**:
  Sensors : MIL 8-4
  Power : DIN 49457
  RS485 : SubD 9-P
- **Coolant connector :** Manufacturer CPC
  Supply, Chassis : LCD 160-06
  Supply, Hose : LCD 220-06
  Return, Chassis : LCD 420-06
  Return, Hose : LCD 170-06
- **Weight** : 13 Kg.

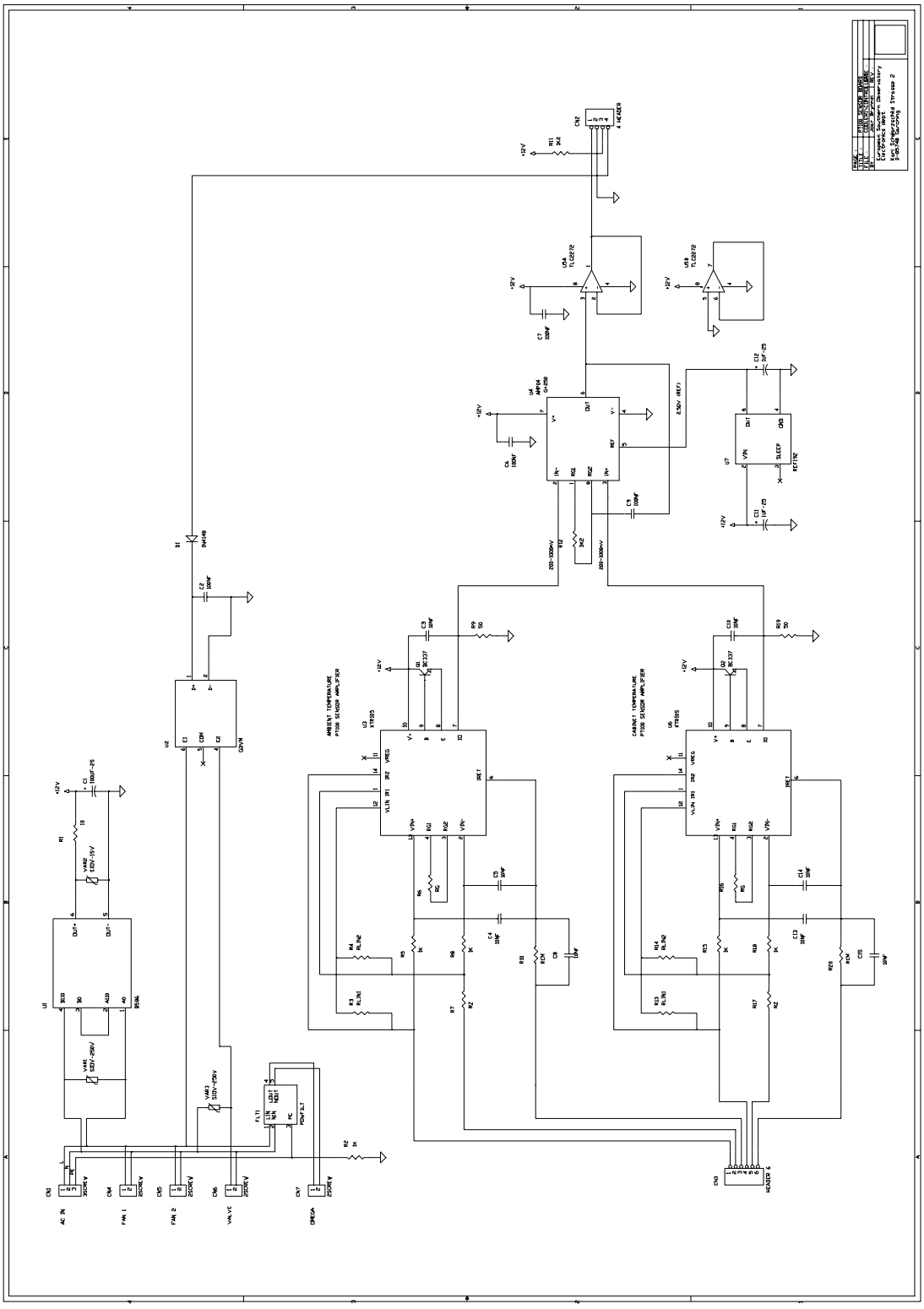
6.2. PACKING LIST

- Cooling unit
- Power cable
- Cooling fluid hose connectors (1x LCD 220-06, 1x LCD 170-06)
- PT100 sensor box [RD2]
- PT100 cable assy, with MIL 8-4 connector, 2x
- VLT-MAN-ESO-17130-2010 Technical manual
- CD-ROM with technical manuals and software tool.

APPENDIX 1A. COOLER INTERNAL SIGNAL WIRING



APPENDIX 2A. PT100 SENSOR BOARD SCHEMATICS



APPENDIX 2. PT100 SENSOR BOARD COMPONENT LIST

PT100 Sensor Board Component List
Revised: Friday, December 10, 1999
Revision: 0

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Item	Qty	Reference	Part	
1	1	CN1	3SCREW	RS 101-4763
2	1	CN2	HEADER 4	
3	1	CN3	HEADER 6	
4	4	CN4,CN5,CN6,CN7	2SCREW	RS 101-4757
5	1	C1	100UF-25	Elyt 0.1"
6	4	C2,C6,C7,C9	100NF	ML 0.2"
7	8	C3,C4,C5,C8,C10,C13,C14, C15	10NF	ML 0.2"
8	2	C11,C12	1UF-25	Tantal 0.1"
9	1	D1	1N4148	Axial
10	1	FLT1	POWFILT	RS 213-6909
11	2	Q1,Q2	BC337	
12	1	R1	10	0.1"
13	5	R2,R5,R8,R15,R18	1K	0.1"
14	2	R3,R13	RLIN1	33K2 1%
15	2	R4,R14	RLIN2	35K7 1%
16	2	R6,R16	RG	78.7 1%
17	2	R17,R7	RZ	80.6 1%
18	2	R9,R19	49.9	1%
19	2	R10,R20	RCM	1K0 0.1"
20	1	R11	1K2	0.4"
21	1	R12	RGAIN	3K20 1%
22	1	U1	B586	RS 211-9831
23	1	U2	G3VM	OMRON
24	2	U3,U6	XTR105PA	Burr-Brown
25	1	U4	AMP04F	Analog Devices
26	1	U5	TLC2272C	Texas
27	1	U7	REF192G	Analog Devices
28	2	VAR1,VAR3	S10-K250	Siemens
29	1	VAR2	S10-K17	Siemens

APPENDIX 3. PARTS LIST

	Part	Quantity	Order Number	Manufacturer	Distributor
1	19'' chassis type CS2007	1	2,007,541,9	Knürr	Knürr
2	Heat Exchanger with fan	2	721STBDM2	Thermatron Engineering	MB
3	Omega Temperature controller	1	CN 77330-C4	Newport	Newport
4	Thermo Valve Actuator	1	M4450A 1009	Honeywell	Honeywell
5	2-way Valve	1	V5822A 1022	Honeywell	Honeywell
6	Anschluss-Verschraubung 3/8''	2	CAN-15T	Honeywell	Honeywell
7	Fan-cable	2	028-555230B	Vero	Vero
8	Kühlwasser-Kupplung 3/8'' BSPT	1	LCD 100-06 BSP	CA	Keller
9	Kühlwasser-Kupplung 3/8'' ID 9,6	1	LCD 170-06	CA	Keller
10	Kühlwasser-Stecker 6,4 ID	1	LCD 420-04	CA	Keller
11	Kühlwasser-Stecker 3/8'' ID 9,6	1	LCD 220-06	CA	Keller
12	Schottverschraubung, 3/8'' G-Gewinde	1	0117 00 17	Legries	MFE Vertiebs GmbH
13	Einschraubschlauchnippel 3/8'' – 6mm	1	sf-115.7	Schwer Fittings GmbH	Schwer Fittings GmbH
14	Ganze Muffe DN10 3/8'' AISI 316 Ti	1	sf-101.7	Schwer Fittings GmbH	Schwer Fittings GmbH
15	Schlauch	ca. 1m	PB4	Swagelok	B.E.S.T. Ventil GmbH
16	1-Ohr Klemmen 13,8 RER	6	13,8mmRER	Hans Oetiker GmbH	Hans Oetiker GmbH
17	Kabelkanal	1	12 H 4576	N.N.	Bürklin
18	Kunstoff-Gehäuse	1	60 H 3332	Teko	Bürklin
19	Kabeldurchführung PG7	6	12 H 2760	Lapp	Bürklin
20	Kabeldurchführung PG9	1	12 H 2761	Lapp	Bürklin
21	Gegenmutter PG7	4	06 N 3680	Lapp	Bürklin
22	Gegenmutter PG7	2	12 H 2831	Lapp	Bürklin
23	Gegenmutter PG9	1	12 H 2833	Lapp	Bürklin
24	MIL-connector	2	851.02.R 8-4P	Souriau	MPS
25	Netzfilter 230V/4A	1	FN 365-4/05	Schaffner	Spoerle
26	Beschriftungsfelder	6			
27	Sub-D connector	1	DE-9S-A197-K91	Amphenol	Spoerle
28	Steuerplatine (see component list)	1	CS-P-1929	ESO	ESO
29	Cooling unit – top plate (see drawing)	1	Cooler1.skd	ESO	Böhm & Wiedemann
30	Cooling unit – bottom plate (see drawing)	1	Cooler2.skd	ESO	Böhm & Wiedemann
31	Cooling unit – back plate (see drawing)	1	Cooler3.skd	ESO	Böhm & Wiedemann
32	Cooling unit – front plate (see drawing)	1	Cooler4.skd	Knürr	Böhm & Wiedemann
33	Screw M5 x 6mm counter-head (top, bottom, back-plate)	16	5,041,589,8	Knürr	Knürr
34	Federmuttern M5	10	5,041,503,9	Knürr	Knürr
35	Screw M4 x 20mm counter-head (heart-point)	2	16 H 142	N.N.	Bürklin
36	Screw M5 x 10mm cylinder-head (Kunststoffgehäuse)	4	14 H 884	N.N.	Bürklin
37	Screw M4 x 6mm cylinder-head (cooler)	12	14 H 790	N.N.	Bürklin
38	Washer M4 (cooler)	12	16 H 862	N.N.	Bürklin
39	Washer M4 copper blank (earth-point)	3	ESO-stock	N.N.	Kluxen
40	Nuts M4 copper blank (earth-point)	2	ESO-stock	N.N.	Kluxen
41	Fächerscheibe M4 (earth-point, cooler)	15	17 H 202	N.N.	Bürklin
42	Screw M2,5 x 8mm cylinder-head (MIL-connector)	8	14 H 766	N.N.	Bürklin
43	Screw M3 x 10mm counter-head (line filter)	2	16 H 126	N.N.	Bürklin
44	Screw M2 x 6mm cylinder-head (ident. plate)	12	16 H 100	N.N.	Bürklin
45	Hex-screw, washer,nut for Sub-D connector	2	ESO-stock	Cannon	Spoerle